Pandemic Effects Predictive Planning Tool for Operational Assessment

Presentation to

Armed Forces Epidemiology Board

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Outline

- Prediction and Analysis in Complex Systems
  - Probabilistic Sampling Design and Analysis
  - Geospatial Analytics
  - Prediction of Pandemic Disease
- Pilot Demonstration: Impacts of a Global Pandemic on Continuity of Military Operations

Prediction and Analysis in Complex Systems

Probabilistic Sampling Design and Analysis

Challenges of Sampling

- Study design and sampling methodology face the following challenges:
  - Must sample/inspect within feasibility constraints. How many samples are needed, in which populations, at what locations to ensure confident decisions? Cannot sample 100%.
  - When planning for or responding to a chem/bio/rad terrorist event, ad hoc, indefensible approaches have been used for determining number and location of samples. How Clean is Clean?
  - Sampling and analysis costs are often major part of overall cost.

- DOD currently cannot fully meet these challenges because of the following barriers:
  - Variability and complexity of numerous sampling objectives by various planning and response teams and agencies, ranging from pre/post deployment monitoring, to forensics to remediation.
  - Statistical expertise limited at DHS, DOE, DOD, EPA and other agencies.

Probabilistic Sampling Design and Analysis

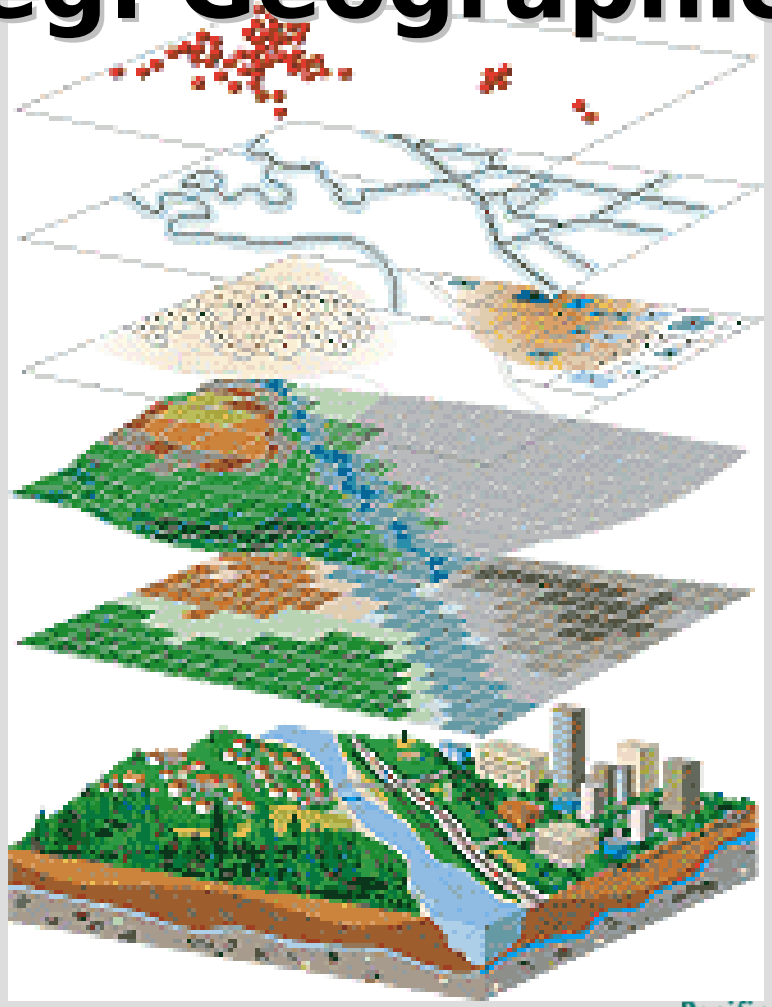
- Visual Sampling Plan (VSP) provides statistical solutions to sampling design, world-class mathematical and statistical algorithms, and a user-friendly visual interface
- Geospatial sampling design and analysis methods
- Combined judgmental and probabilistic sampling design and statistical assessment methods
- Bayesian probabilistic methods
- Optimal sensor placement integrated with dispersion models

Geospatial Analytics

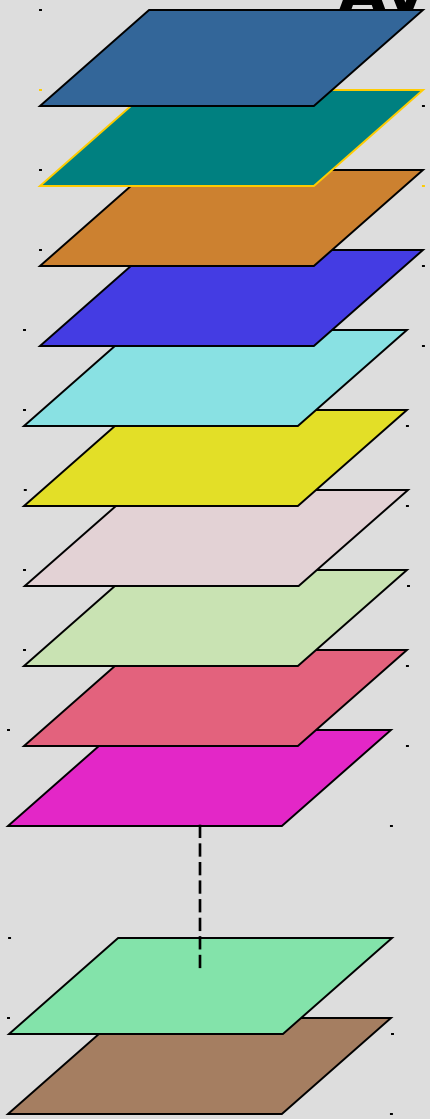
Fundamental Challenge for Visual Analytics Technology

Analyze masses of data in different formats and types, from different sources, with highly varying degrees of confidence levels, within time frames required for rapid decision making, to reduce risk from exposure to pandemic disease and bioterrorism.

Spatially Related Datasets (eg. Geographic)



Candidate Data Sets for a Pandemic Geographical Information System (GIS) e.g., Avian Flu



Bird Migration (Flyway) Routes

Outbreak Locations

Infected Dead Bird Sites

Infected Live Bird Sites

Environmental Sample Sites

Import/Smuggling Sites

Pet Trade Incidents

Illegal Poultry Imports

Live Bird Markets

Exotic Food Markets/Restaurants

Hospital Beds

Vaccine Stores

DOD is faced with the following challenge in visual analytics:

- Creating and implementing an integrated (data-to-decisions) and forward-
looking (predictive or anticipatory) visual analysis capability to predict, prevent,
and respond to emerging pandemic diseases and to an evolving, dynamic and
unexpected array of terrorist attacks

DOD cannot fully meet these challenges because of the following barriers (technical, political, social, etc.):

- Discovering and relating threat clues, transactions and other indicators in
diverse, massive and dynamic information streams that overwhelm today's
technologies
- Understanding risks in the context of dynamic threat scenarios (scenarios driven by history, by human imagination, or by actual evolving data)
- Integrating sensor data (point measurements, imagery), transactions, and
facts (people, places, events) in an integrated decisions support environment,

Prediction of Pandemic Disease

Pandemic Disease as a Complex System

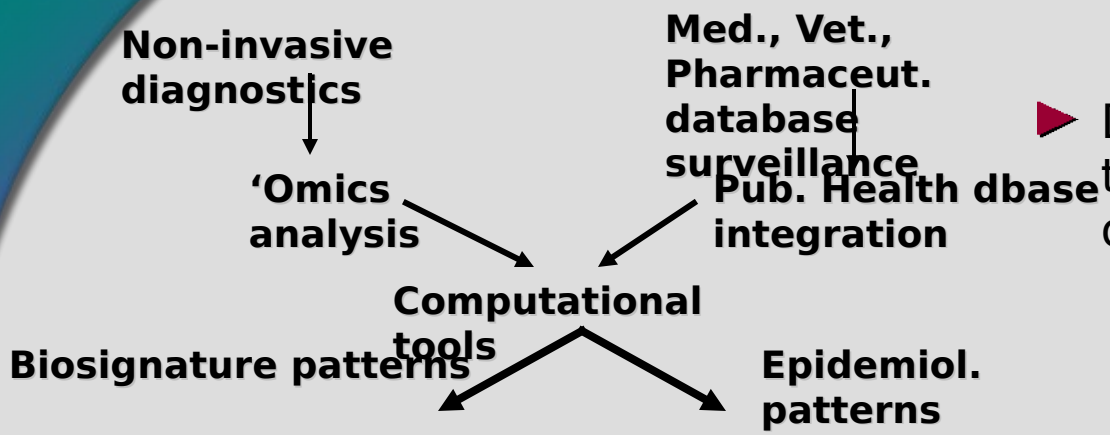
Pandemic disease involves the following challenges:

- US interests threatened by worldwide increase in incidence, and in human pathogenicity, of zoonotic and other emerging infectious diseases of pandemic potential
- Increased globalization, international travel and expeditionary military operations raise imminent threat of rapid, worldwide dissemination of infectious disease threats, posing public health and national security threat to US
- Need to detect exposure and predict potential infectious disease outbreaks prior to occurrence of symptoms in humans, to protect US citizens and assets
- **Need to predict effects of pandemic disease on continuity of military operations, and civilian operations supporting critical infrastructure**

DOD cannot fully meet these challenges because of the following barriers:

- Environmental and biological factors driving movement of animal and other diseases into human populations, human-to-human transmission, and increased human virulence poorly understood
- Limited tools for early detection of biosignatures of exposure in animals and humans
- Inadequate international surveillance for emerging infectious diseases
- **Limited modeling and simulation capabilities to predict potential effects of pandemic disease**

APPROACH

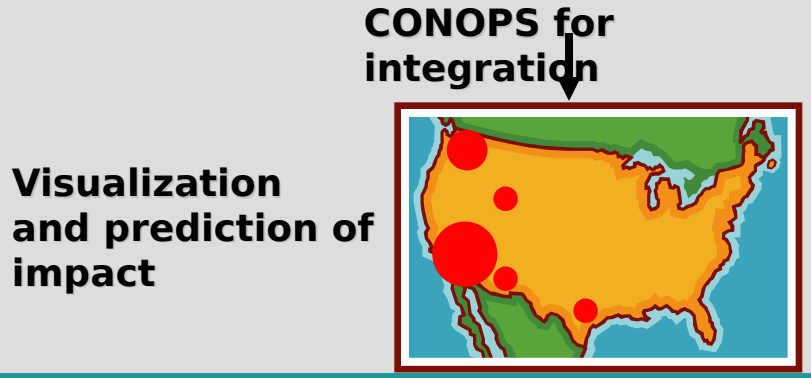


- Development of biosurveillance tools, methods and concepts of operation…

  that enable non-invasive detection of biosignatures of pre-symptomatic exposure…

  and integration of public health database analyses…

  for spatial-temporal visualization of disease occurrences and biosignature dynamics, to predict public health and national security impacts.



Example: Epidemiological detection of infectious disease outbreak requir correlation in real time with biosignatures of exposure, to predict public h and national security impacts

Impacts of a Global Pandemic on Continuity of Military Operations

Pilot Demonstration

Plausible Scenario

- Avian influenza (AI) virus mutates to a human-to-human transmissable form in Pacific rim and propagates to Hawaiian Islands
- Outbreak is coincident with start of a major U.S. military deployment operation
- Goal is to predict impacts to transportation Hickam AFB and potential mitigation strategies

Pilot Demo Objectives

- Demonstrate ability to model and address potential impacts of global pandemic on continuity of strategic airlift operations and achievement of mission objectives
  - Use USTRANSCOM Aerial Port of Debarkation Plus (APOD+) model
  - Predict ability to onload and transport cargo and personnel (PAX) when operating under pandemic

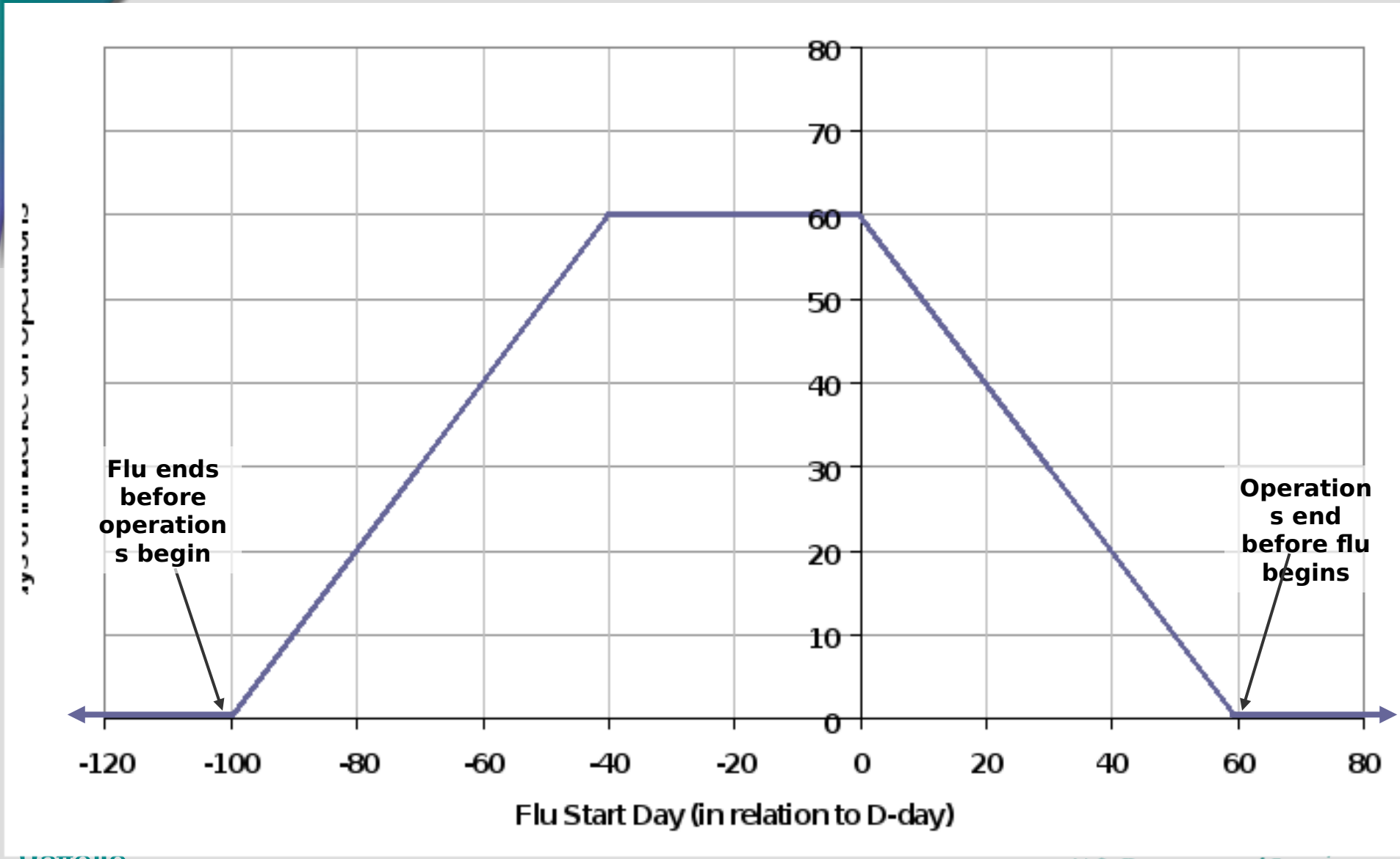
How Would a Pandemic Impact Ops?
Some Preliminaries

- Impact a pandemic will have on a given operation is a function of several factors
  - Flu duration, F_d (days)
  - Operations duration, O_d (days)
  - Flu start relative to start of operations, F_s
  - Days of influence on operations, D_i

$$D_i = f(F_d, O_d, F_s)$$

Days of Influence vs. Flu Start Day

(Flu Duration = 100 days, Operations Duration = 60 days)



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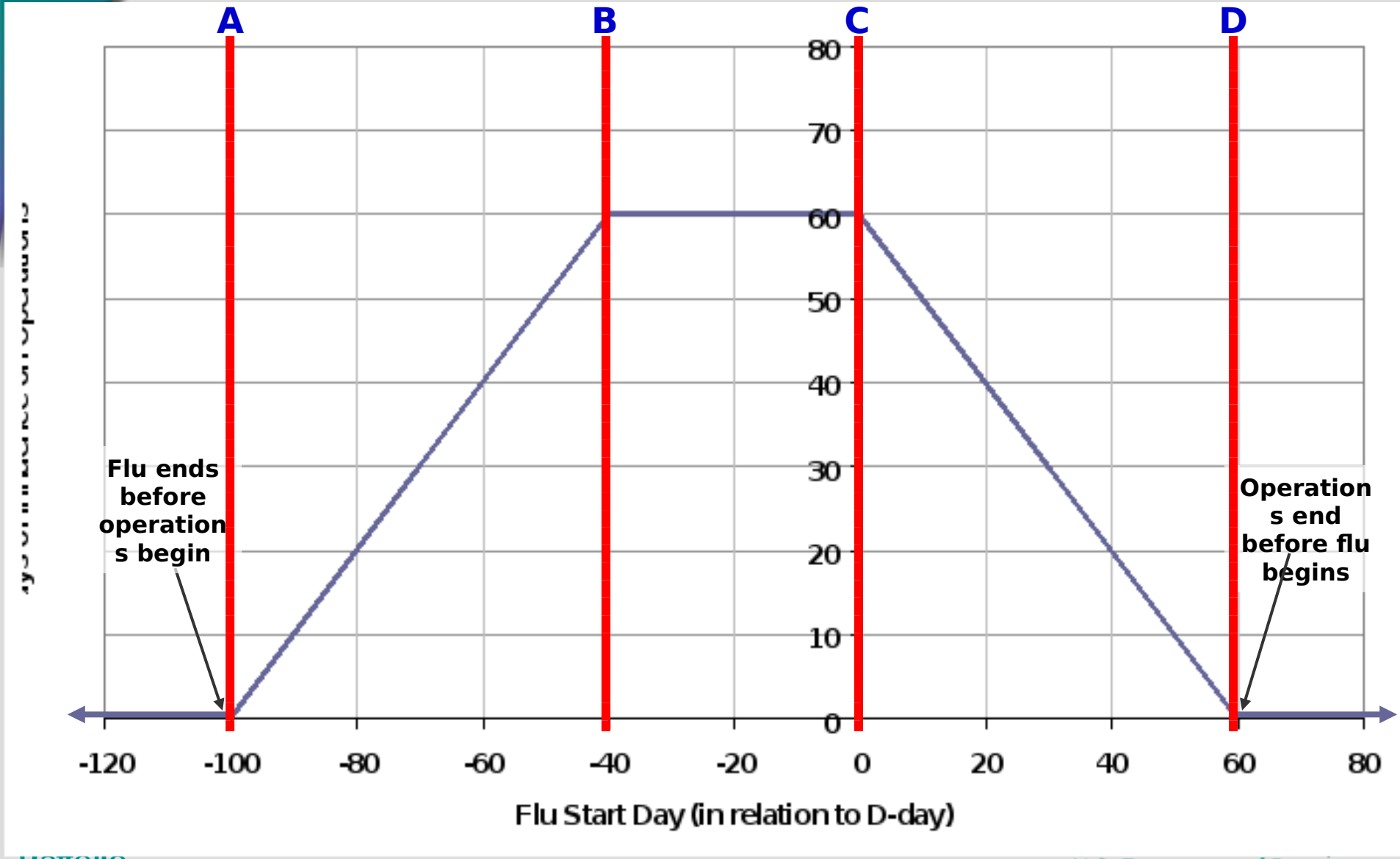
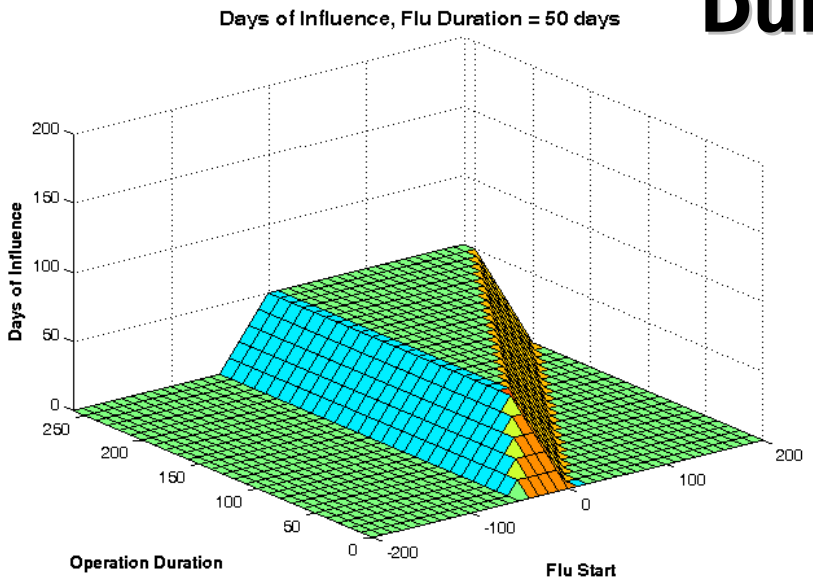
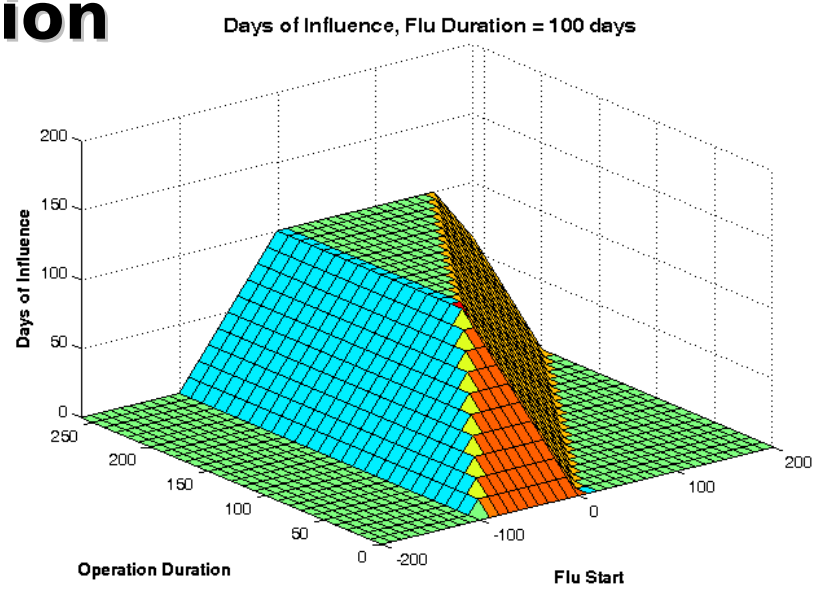


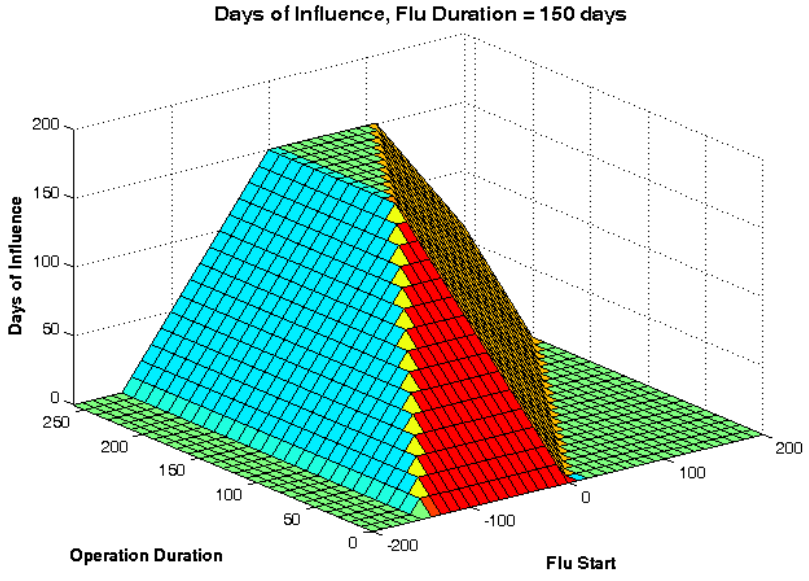
Mathematical Relations

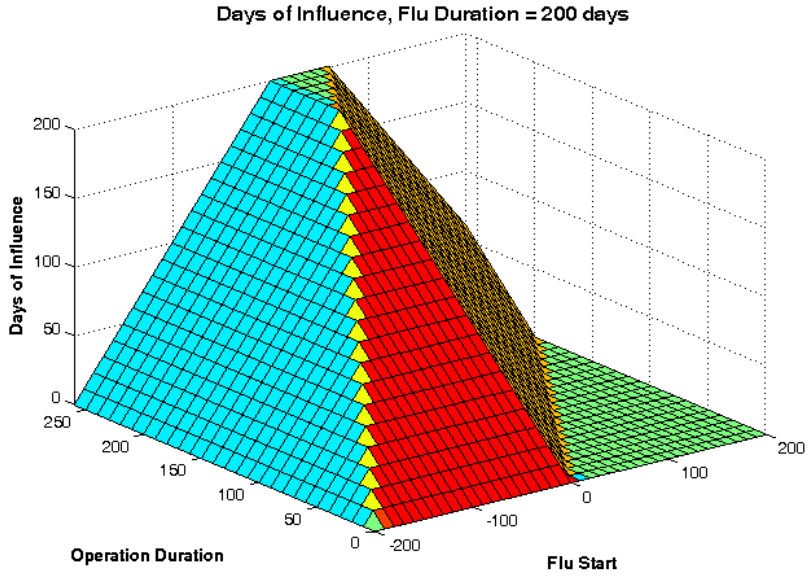
$$D_i = \begin{cases} 0 & F_s \le A \\ F_s + F_d & A < F_s \le B \\ F_d & B < F_s \le C \\ O_d - F_s & C < F_s \le D \\ 0 & D < F_s \end{cases}$$

Days of Influence vs. Flu Start Day and Ops Duration





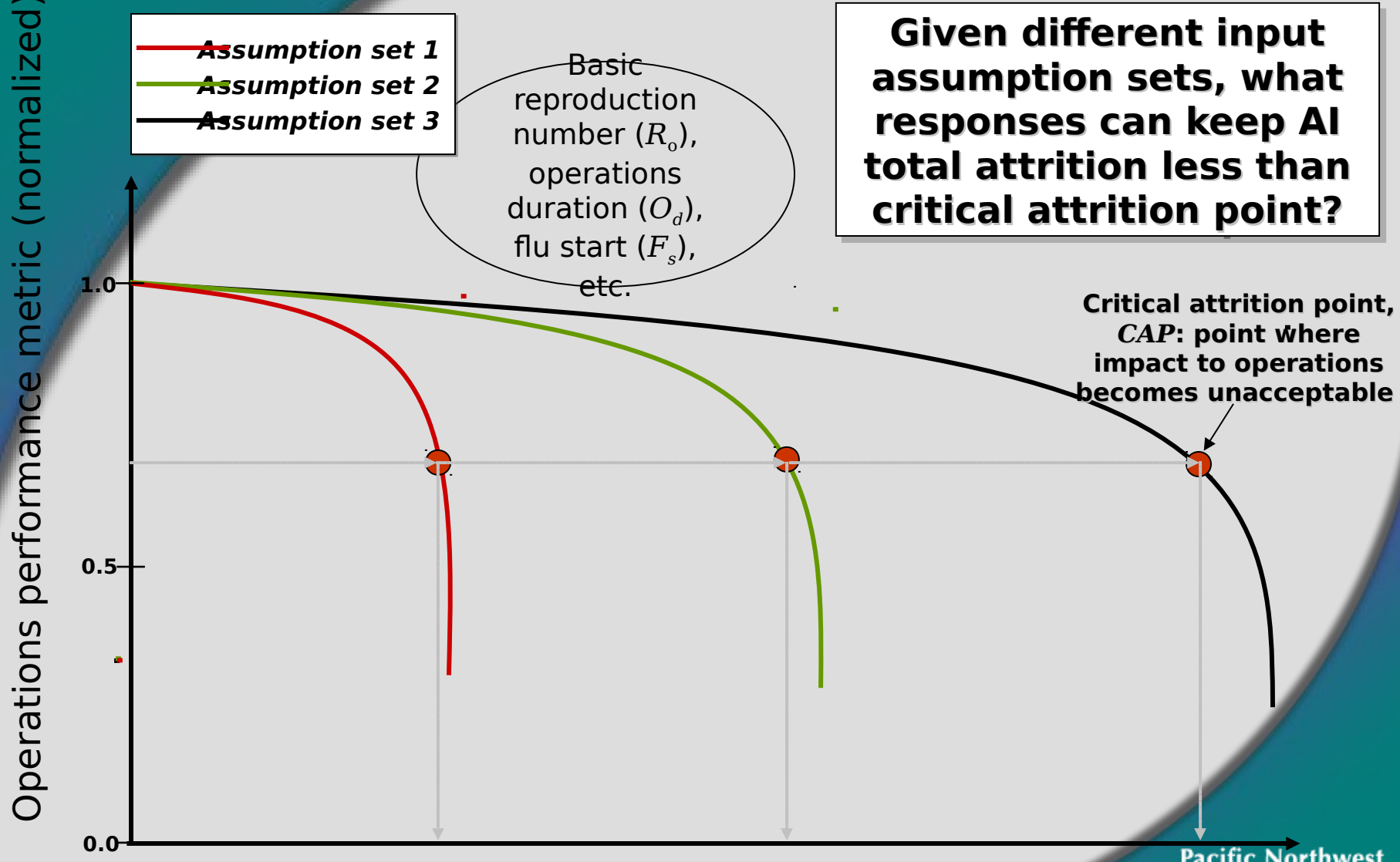




Outcomes

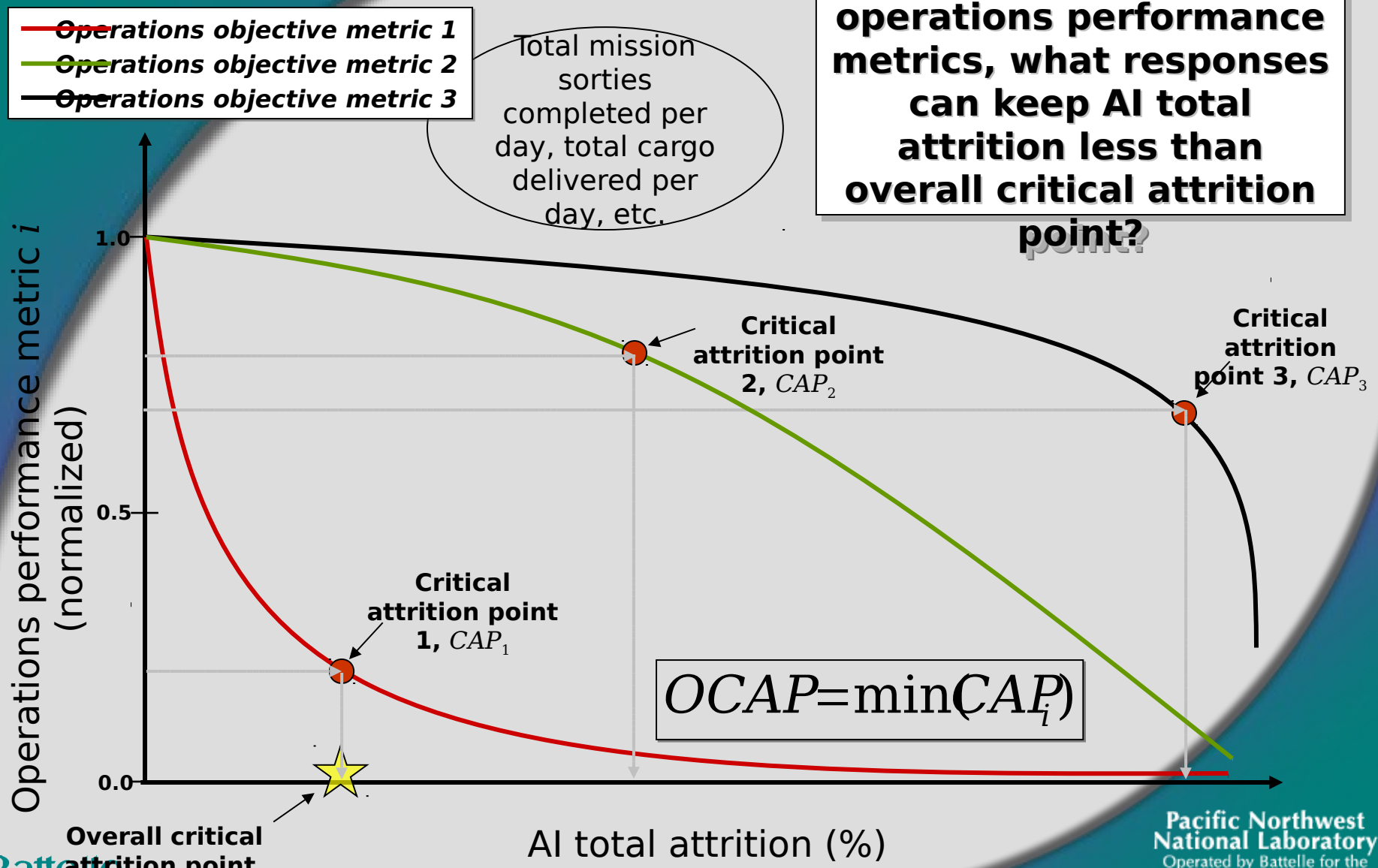
- How much influence a pandemic will have on an operation is a complex, nonlinear function
- Depending on flu duration, operations duration, and flu start timing, pandemic may
  - not affect operations at all
  - seriously affect operations

Different input assumptions
(Fixed operations performance metric)

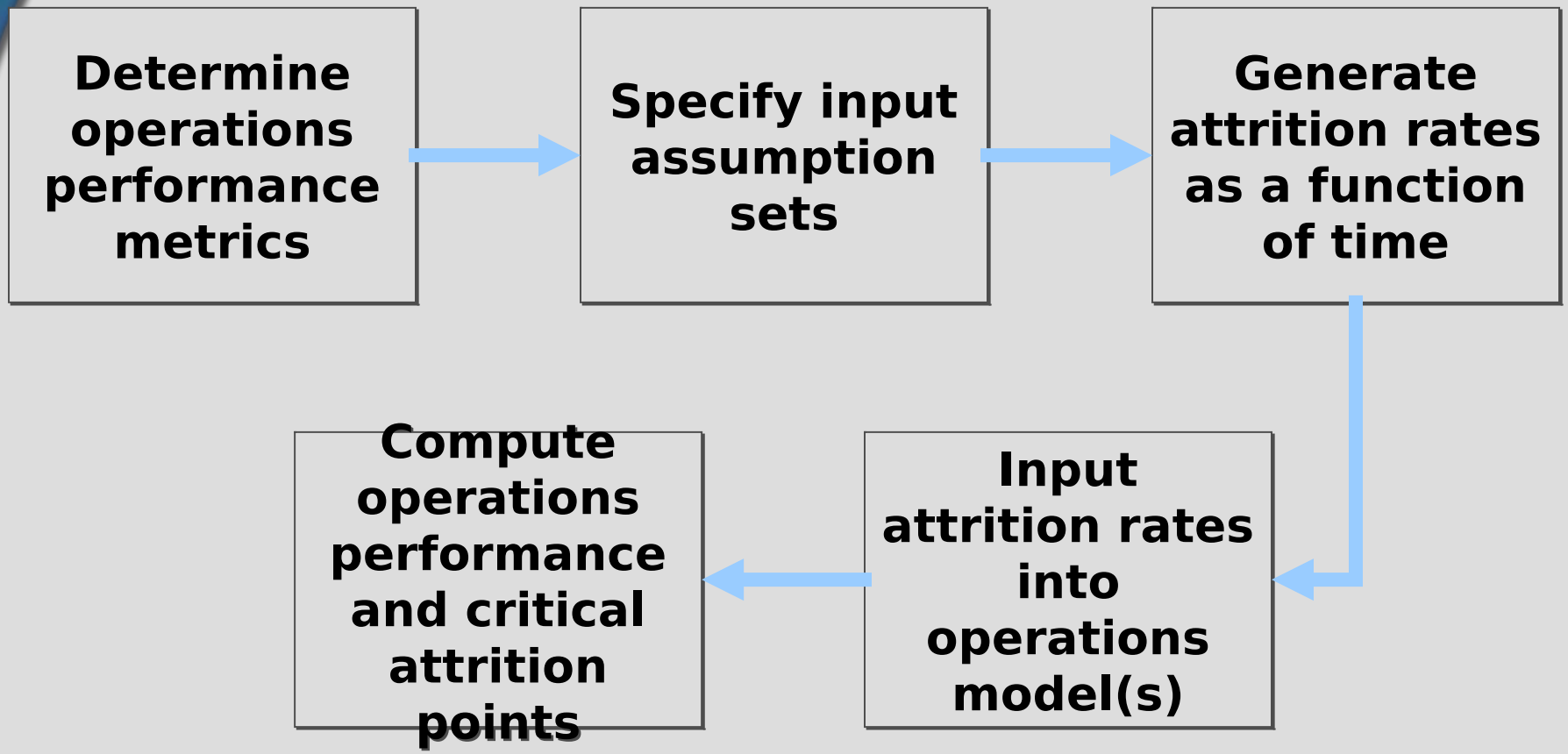


Different military objective metrics
(Fixed input assumption set)

Given different operations performance metrics, what responses can keep AI total attrition less than overall critical attrition point?



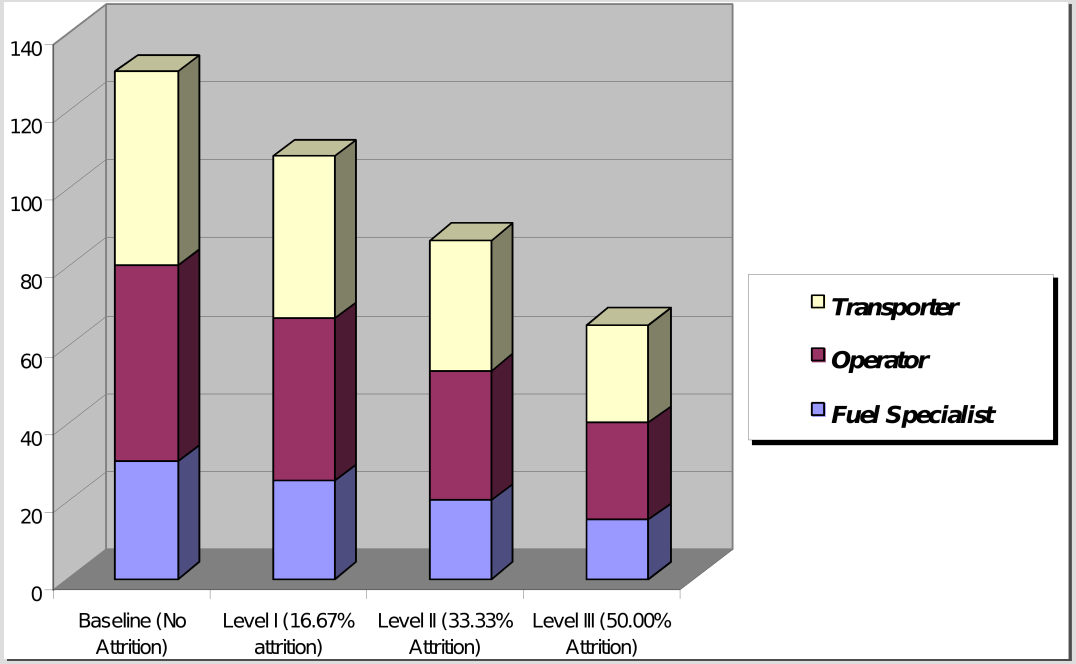
General Modeling Flow Concept



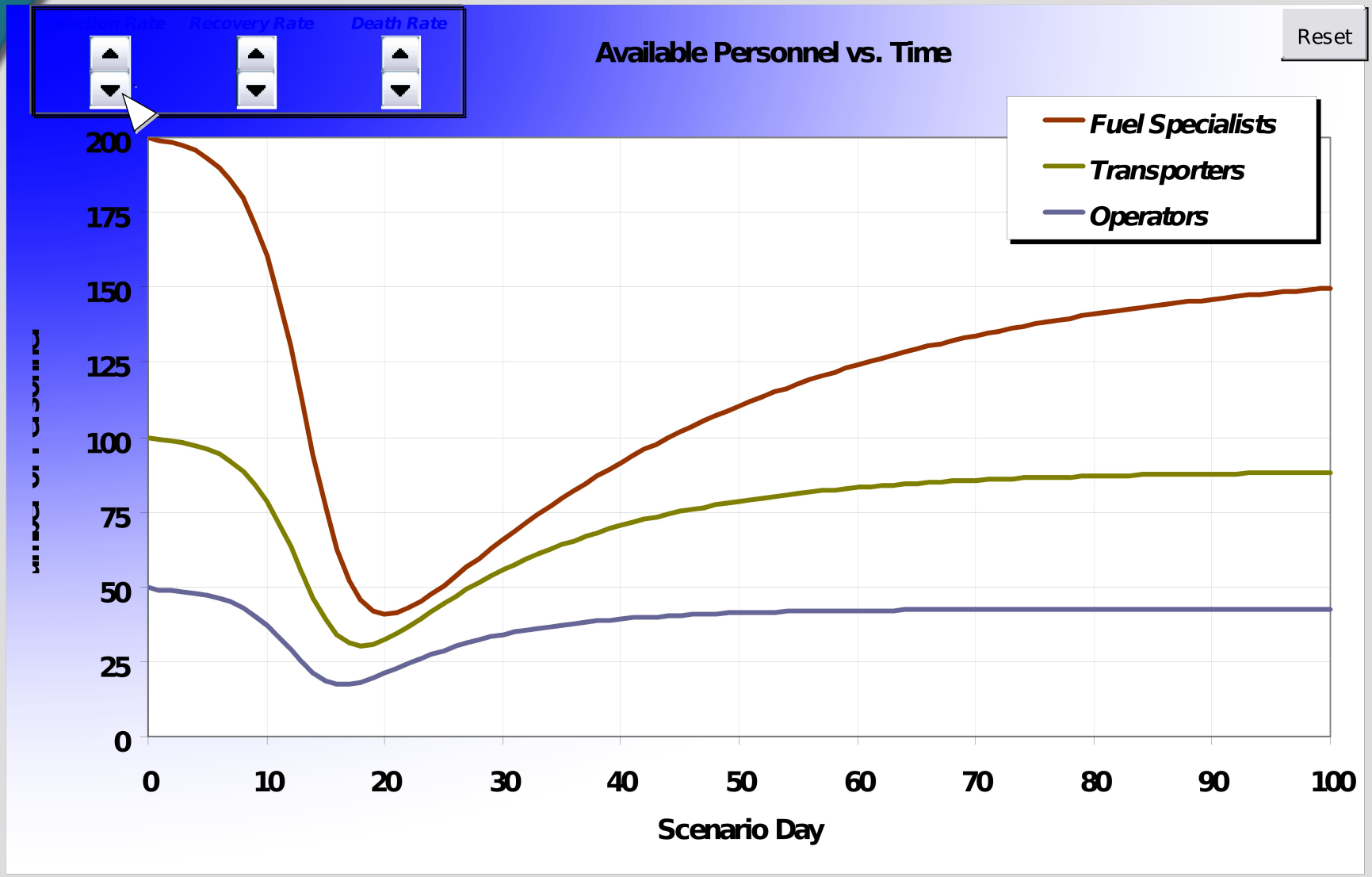
Hickam AFB APOD+ General Modeling Assumptions

- Modeled impact of avian flu pandemic via attrition of Hickam AFB ground operations personnel: fuel specialists, operators, and transporters (notional numbers)
- Four basic Avian Influenza (AI) total attrition rates
  - Baseline: no attrition
  - Level I: 16.67% attrition
  - Level II: 33.33% attrition
  - Level III: 50.00% attrition

Function	Fuel Specialist	Operator	Transporter
Fuel truck ops	X		
Hydrant service equipment ops	X		
Fill-stand ops	X		
Bulk fuel ops	X		
Fuel laboratory ops	X		
Aircraft load teams		X	X
Cargo yard dock teams		X	X
Pallet netting/breakdown		X	X
Truck loading teams		X	X
Documentation teams		X	X
Operate MHE/Ground Equipment		X	



Example: Affect of Different Input Assumptions on Personnel Attrition



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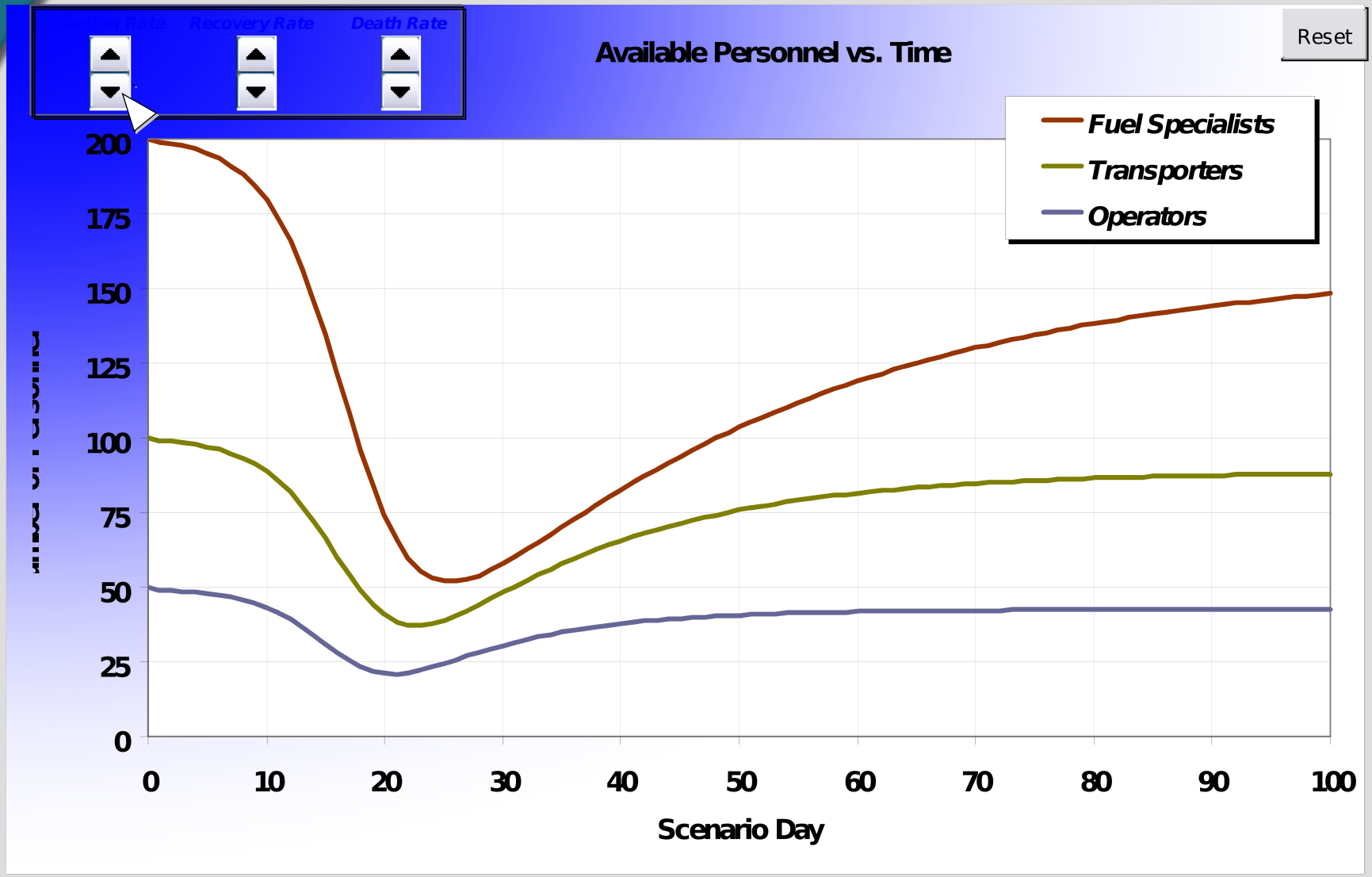

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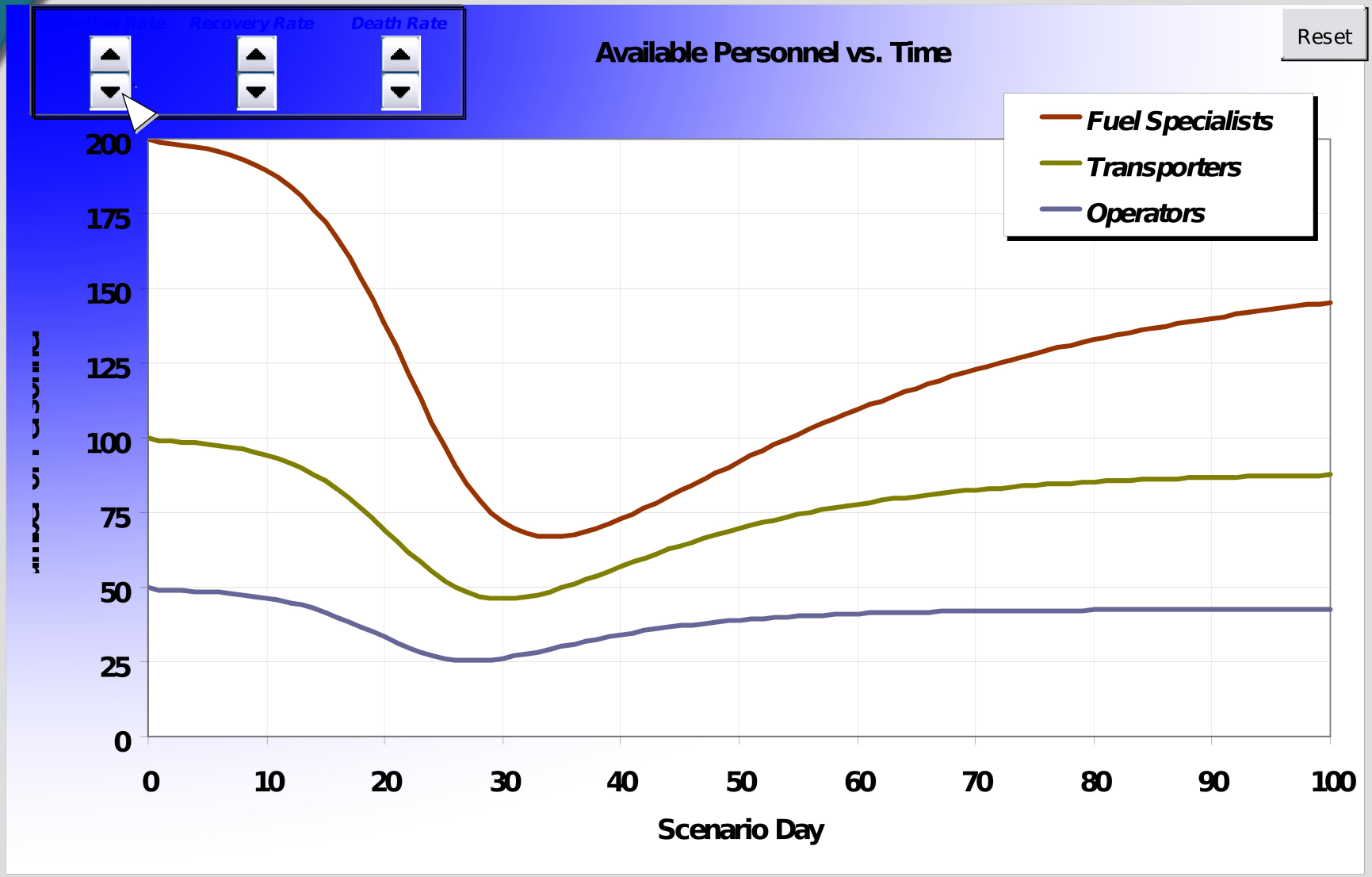

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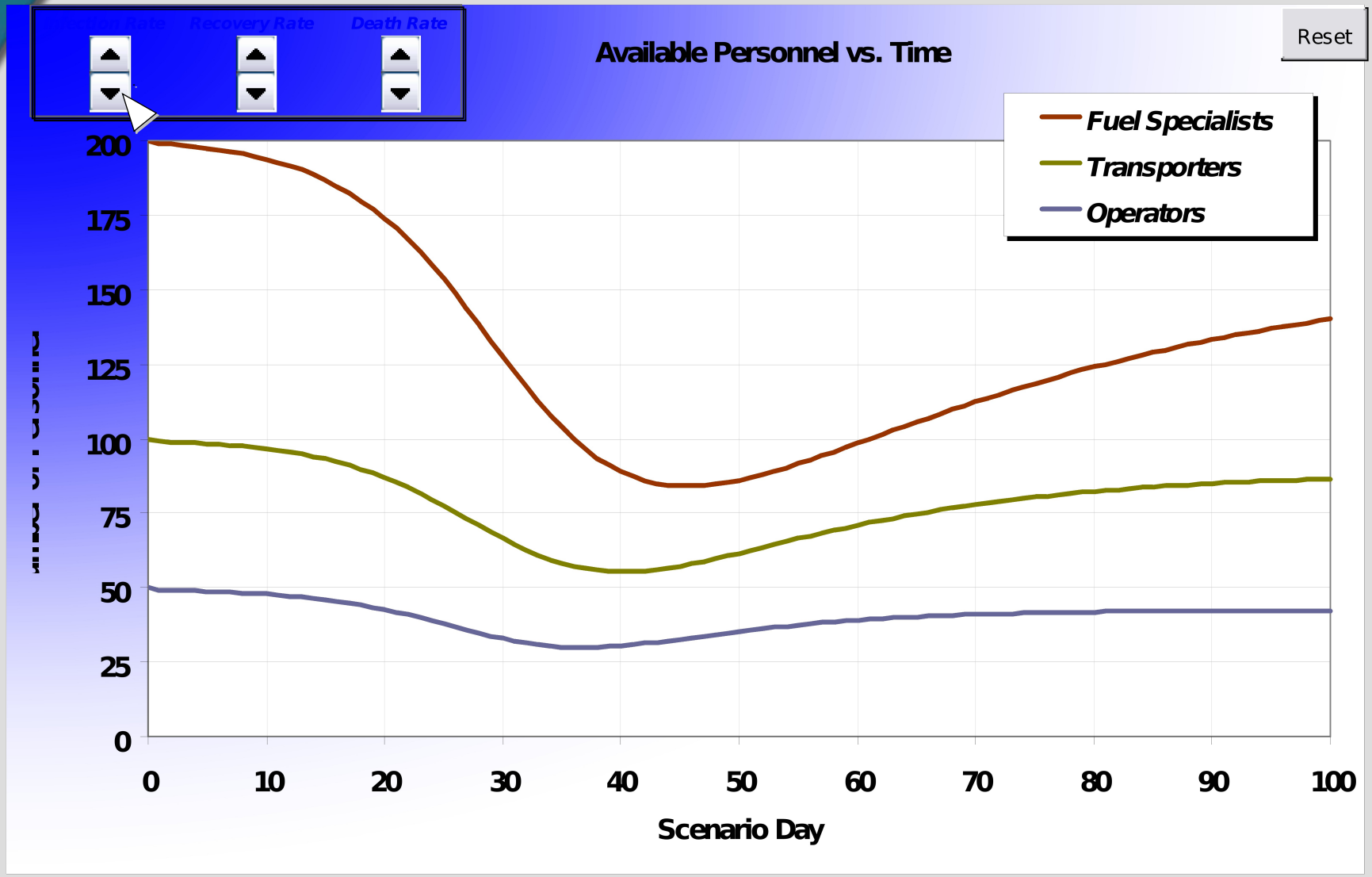

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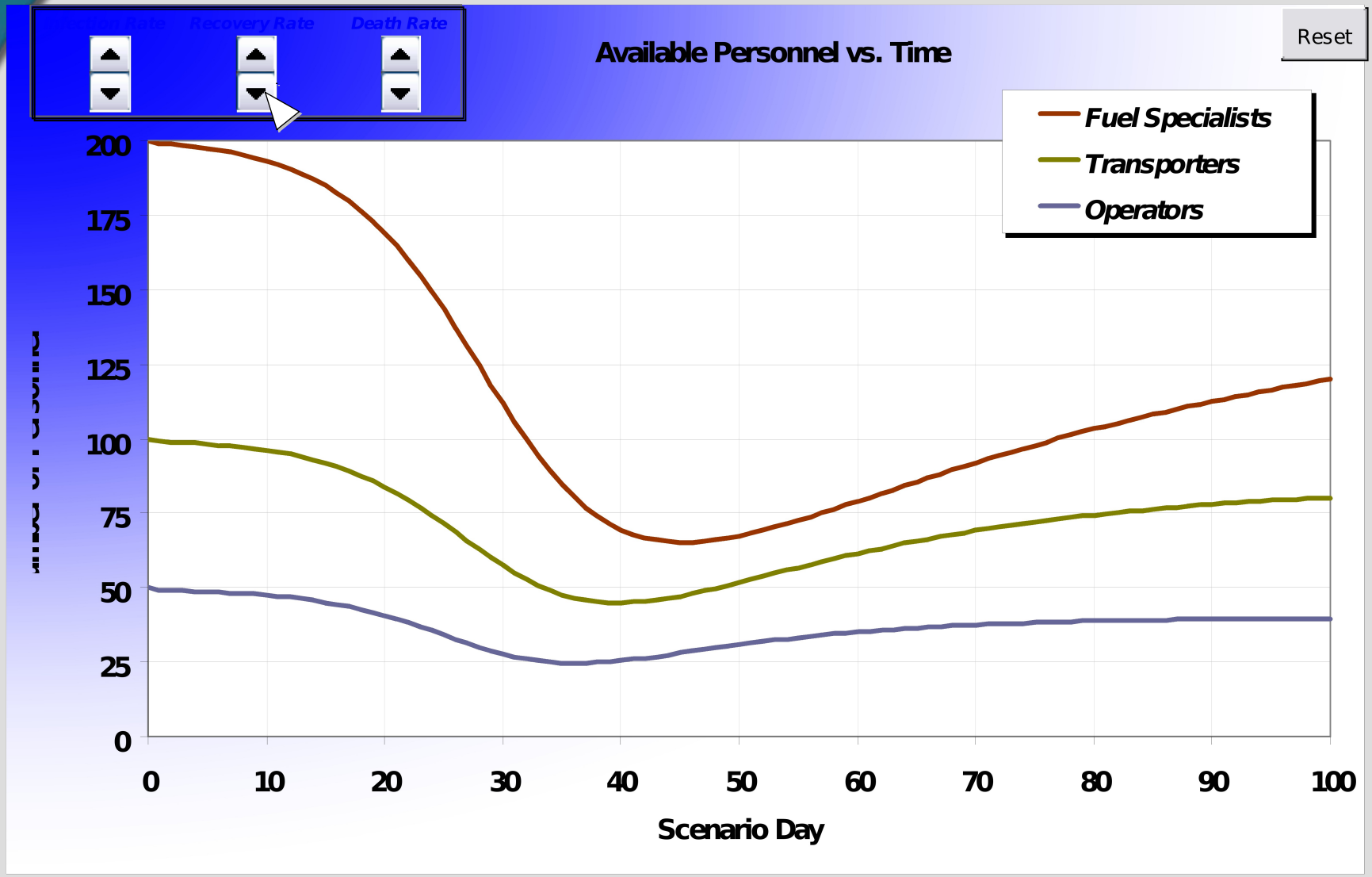

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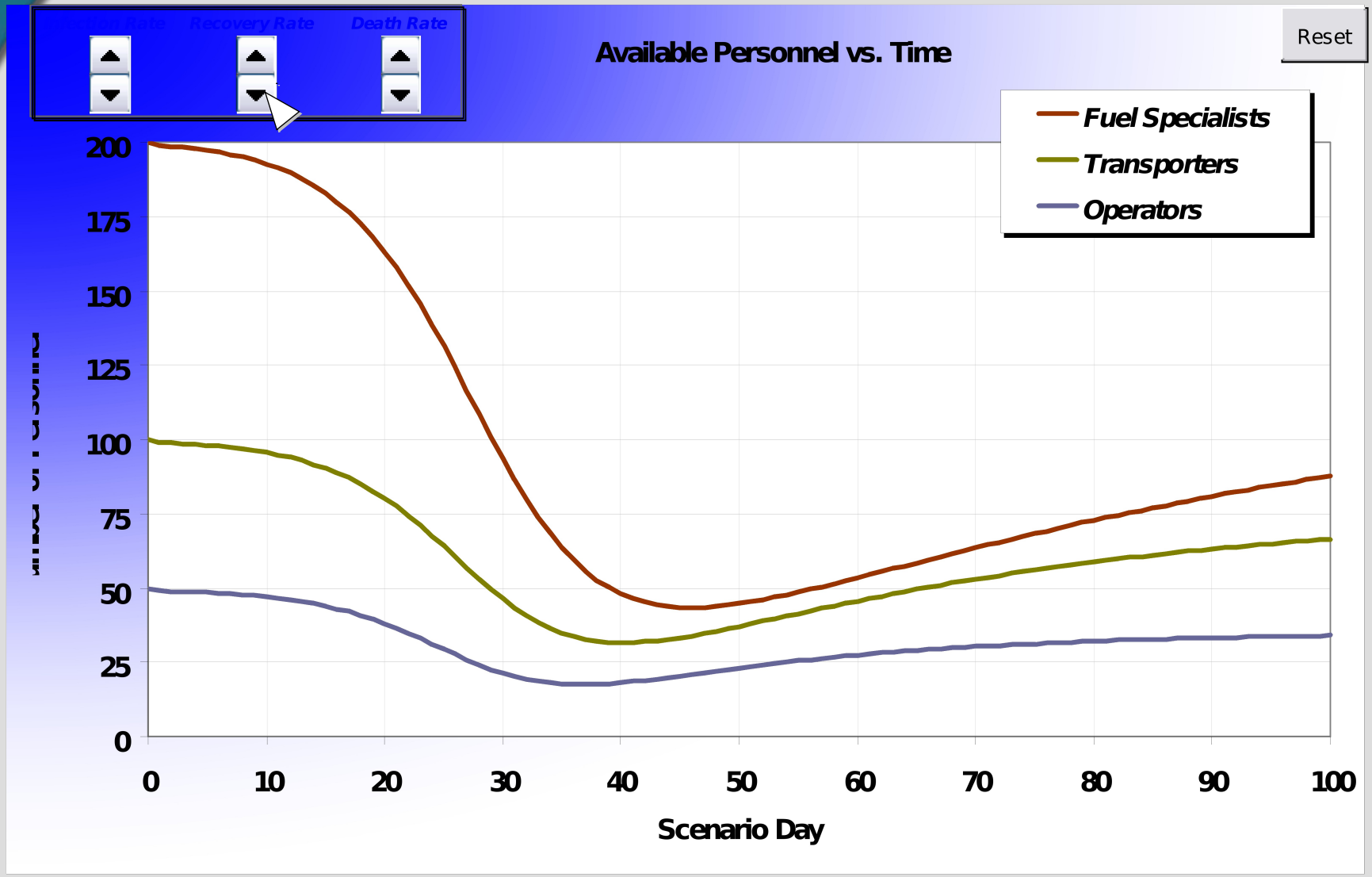

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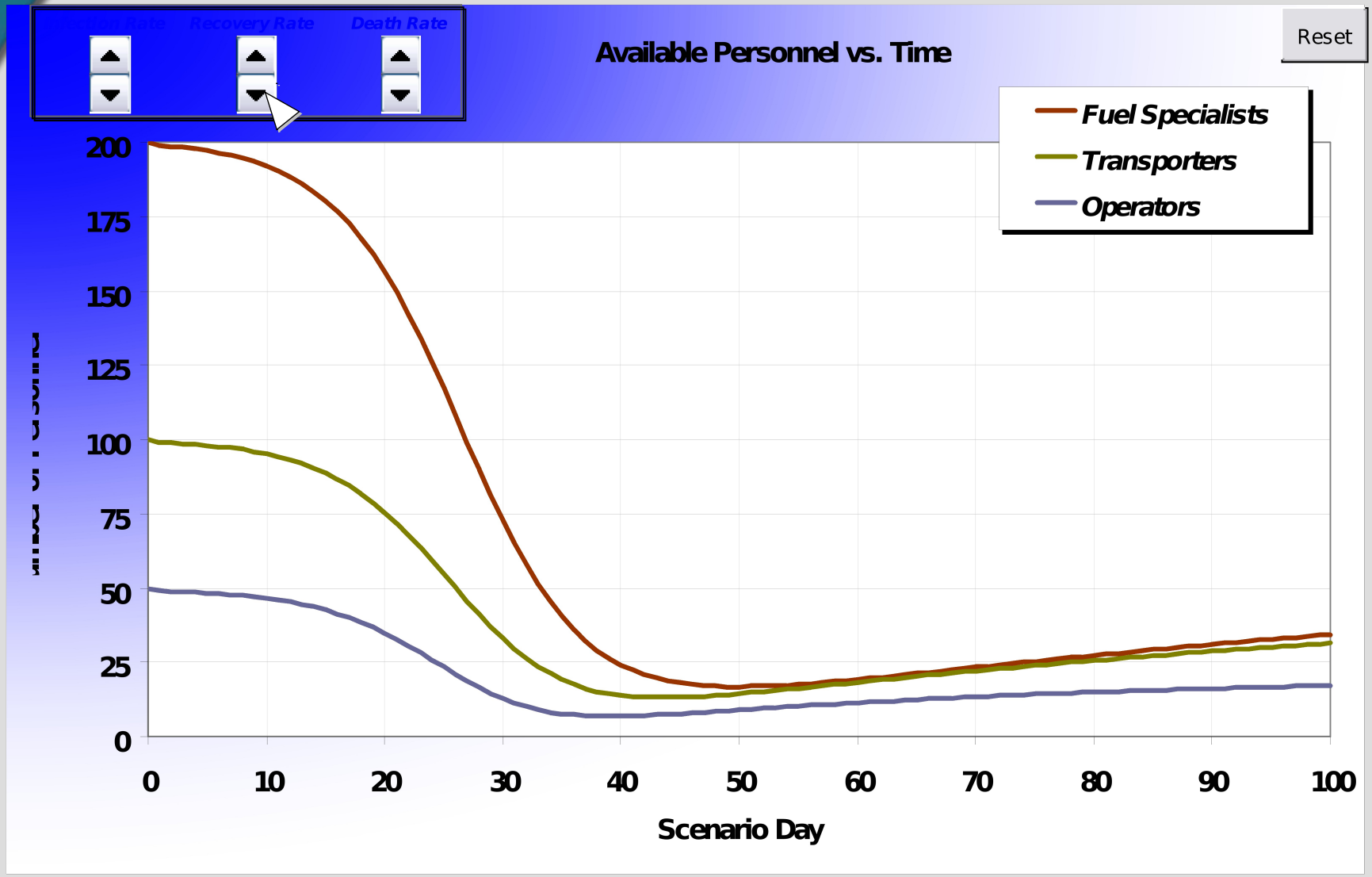
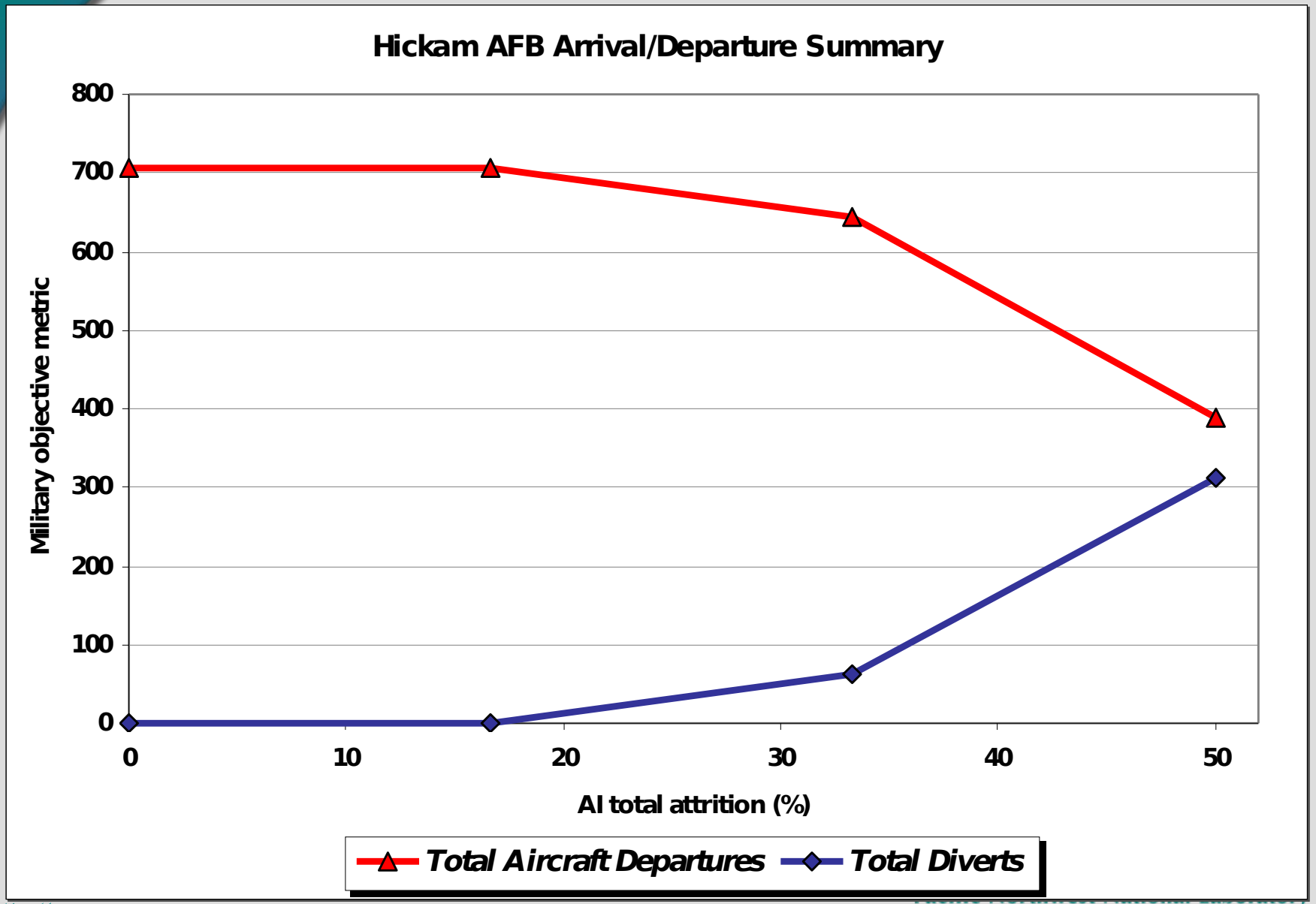
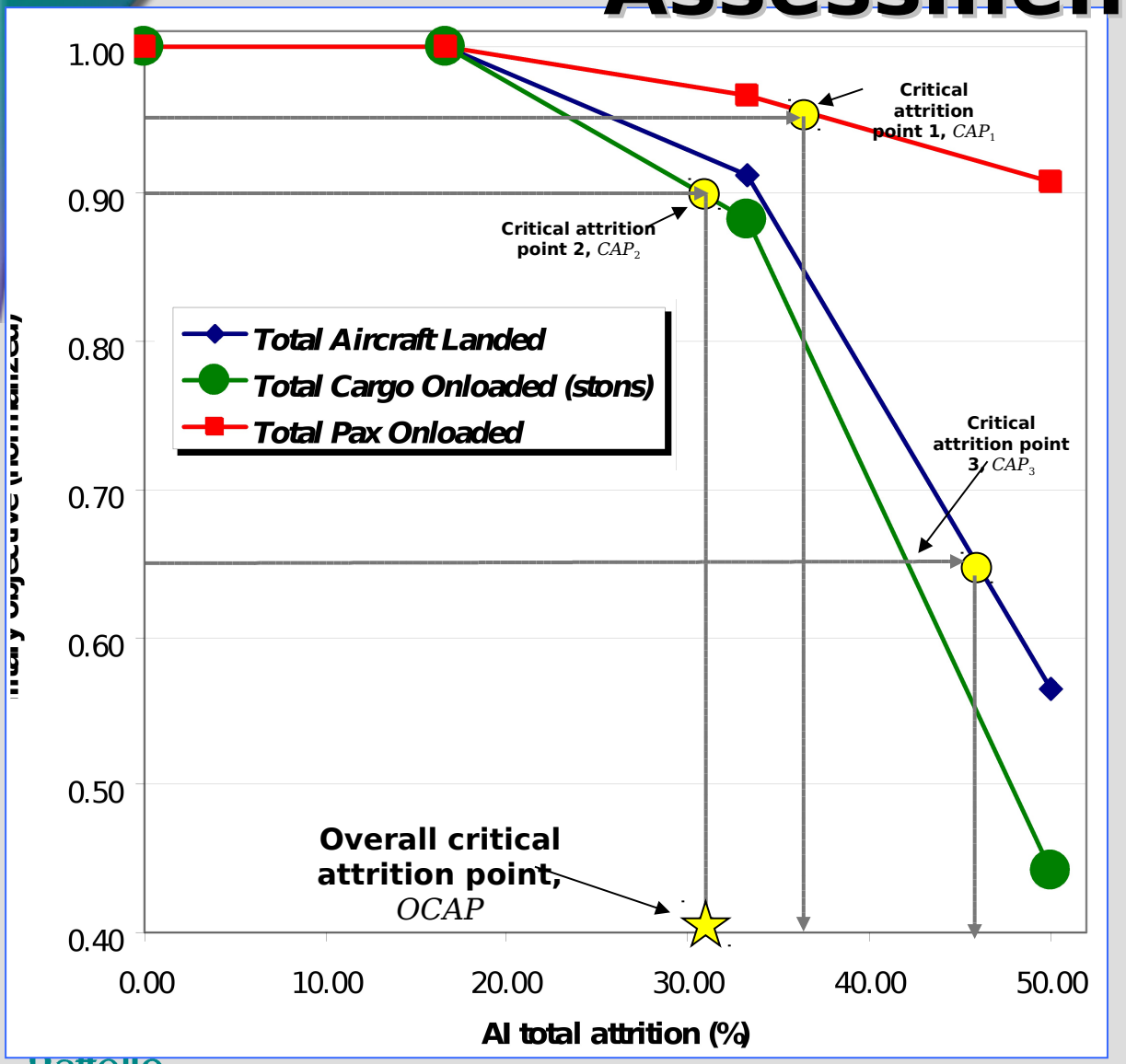


Hickam AFB Impact Summary



(Based on notional data only)

Overall Critical Attrition Point Assessment

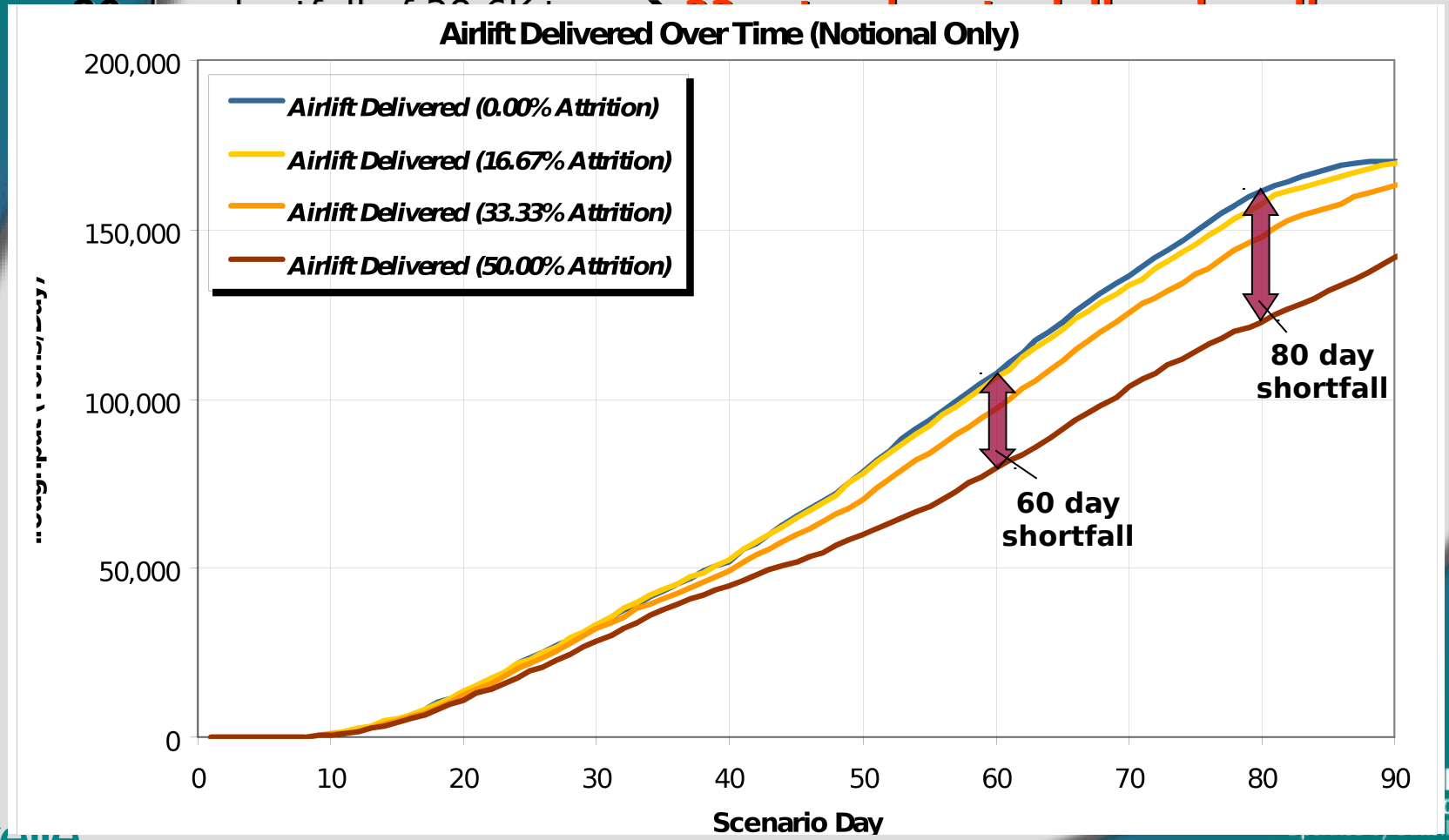


- 95% of baseline PAX onload: $CAP_1 = 37\%$
- 90% of baseline cargo onload: $CAP_2 = 31\%$
- 65% of baseline total aircraft landed: $CAP_1 = 46\%$
- Overall critical attrition point: $OCAP = 31\%$
- Impacts are non-linear responses to input AI total attrition rates
- Has to do with stochastic nature captured in simulation environment

(Based on notional data and notional objectives)

Theater wide bottom line impact

- Avian flu pandemic can cause significant shortfalls, e.g., at 50% AI total attrition
  - **60** day shortfall of 28.0K tons ➔ **18 extra days to deliver baseline amount of cargo**



Recommendations

- Validate epidemiological models on military populations. PNNL:
  - Continue involvement with colleagues at NORTHCOM, Naval Postgraduate School and MIDAS on epi modeling development
  - Use approved epi model(s) to develop attrition rates and input parameters to military operations models
  - Continue to develop “plug and play” interface with ops models
- Expand logistics/combat modeling and other operations modeling. COCOMs:
  - Model entire PACOM/EUCOM transportation network for AOR level impacts on transportation, to include airlift and sealift
  - Incorporate above results into higher level military combat models to examine overall effects on military mission objectives for the combatant commanders
  - Model/assess other impacts to other operations (military and/or civilian)
- Red Team mitigation strategies effectiveness. DOD(HA):
  - Quarantine/Social distancing concepts
  - Antivirals, vaccination rules/priorities
  - Operational concepts for aircraft/aircrew/ground personnel under pandemic disease stress
  - Policies for management and protection of mission-critical non-military support and other civilian personnel (contractors, DOD civilians, dependents)
- Assess effects on Continuity of Operations. AFEB:
  - **Recommend DOD include predictive effects modeling in pandemic disease preparedness and mitigation plans; engage National Labs where appropriate**